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Drill-Stem Testing and Sampling of Deep Frio and Wilcox Reservoirs

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ABSTRACT

Methods of sampling and evaluating geopressured geothermal aquifers in extreme South Texas are discussed. The area of investigation includes Starr, Hidalgo, Kenedy, Willacy, and Cameron counties in the Texas valley and covers representative methods of evaluating the Frio formation (Oligocene) and the Wilcox formation (Eocene).

INTRODUCTION

In recent years, exploratory drilling for petroleum in the Frio and Wilcox formations of extreme South Texas has extended to depths sufficient to provide information on geopressured geothermal aquifers. However, physical evaluation of these aquifers has been sparse. In an attempt to develop quantitative parameters, it will be necessary to gather information from many sources. These include well-log analyses, core analyses, drilling reports, mud logs, etc.

A generalized model well will now be considered for purposes of sampling and evaluating geopressured aquifers in the defined area. Assumptions are based upon data common to the Wilcox and Frio formations of South Texas. A well drilled to a depth of 17,500 feet may be expected to have a bottomhole temperature of approximately 480°F and a pressure of slightly less than 1 psi/ft, or approximately 17,000 psi. A commonly followed drilling and casing procedure is as follows: (1) 20-inch casing set at 600 feet and cemented to the surface with accelerated cement, (2) 13⅜-inch casing set at 8,000 feet and cemented to the surface with high-temperature cement, (3) 9⅝-inch casing set at 14,500 feet and cemented to the surface with high-strength thermal cement, (4) well drilled to total depth using an 8½-inch bit and then completed with a 7-inch, external, flush joint liner set at total depth with surface tie-back capability.

In the Texas valley, Frio sands below a depth of 14,500 feet often have horizontal permeabilities of less than 1 to 4 millidarcys. Vertical permeability is often less than 1 millicarcy, owing to shale lensing. The sands generally have porosities of 20 percent or less. This formation contains water-sensitive clays of montmorillonite, illite, and kaolinite. Bedding plains within Frio sands generally encompass about 80 percent of the exposed sand face. The Frio formation, in many areas, has the tendency to produce sand along with water.

The Wilcox sands encountered in this area are similar to the Frio sands, except they generally contain 20 percent lower permeability and 15 percent less porosity. Both formations contain interstitial water having salinities of less than 8,000 ppm based on well-log evaluations.

SAMPLING AND EVALUATING PROCEDURES

Based on this model well, several testing procedures may be considered.

Electric Wire-Line Testing

Electric wire-line testing could be used to evaluate formations prior to setting the liner at total depth. The basic role of the electric wire-line formation tester in subsurface evaluation is to provide a sample of formation fluid and related pressures adjacent to the well bore at a predetermined depth. The tester (fig. 1)

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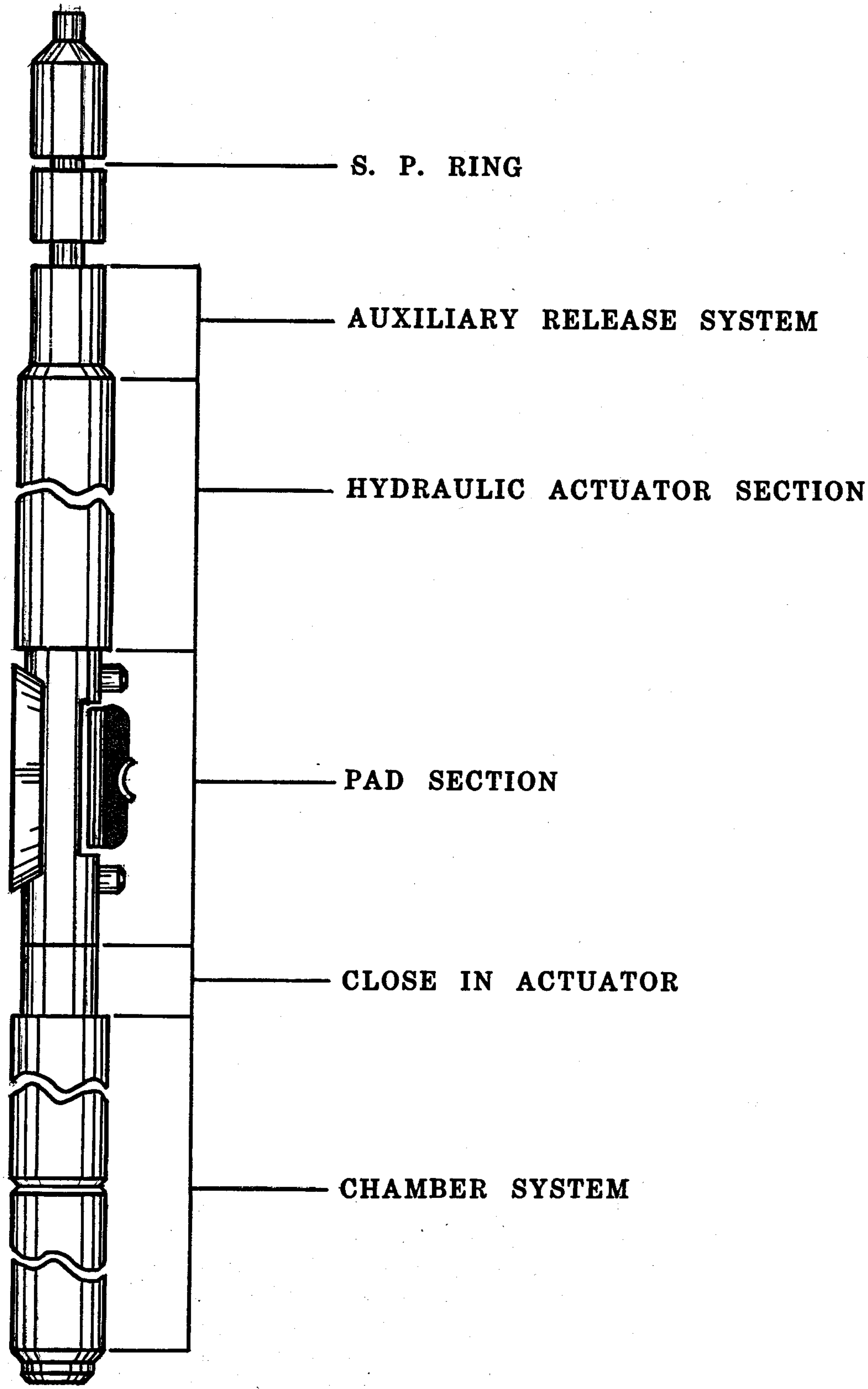

Figure 1. Electric wire-line formation tester.

is lowered into the well to the proper depth, as determined by correlation of the self-potential curve (gamma ray, in some instances) with previous logs. By powering the pad section by means of hydrostatic pressure in the well bore, the pad and backup plate are expanded against the well bore. A pressure seal is formed by this action between the formation and the well bore. While the pad is against the wall, a flow valve is opened by a surface signal, allowing formation fluid to flow into the tool.

As the fluid flows from the formation into the tool, a surface record of the flowing pressure is made. When the chamber fills with formation fluid, a shut-in valve is closed, allowing the recording of shut-in pressure. Hydrostatic pressure is recorded upon release of the pad from the formation seal. The pad retracting force is greater than the expanding force, ensuring positive retraction. At the surface, measurements are made of the chamber pressure and recovery of oil, gas, water, mud, sand, and so forth.

The electric wire-line method has certain inherent limitations. The tool cannot be used at a temperature above 450°F; sample recovery is normally limited to 6 gallons of fluid, and this limited sample often contains invasion water from the drilling fluids. The bottom-hole pressure is not extremely accurate because the formation may be supercharged from pressure surges in normal drilling operations. The amount of recovered fluid would be insufficient to dissipate this pressure.

Conventional Open-Hole Drill-Stem Test

A carefully designed conventional open-hole drill-stem test (see fig. 2) could be used to evaluate flow capacity, permeability, energy transmission, formation damage, and the possibility of a permeability barrier. The drill-stem test should be run as the well is drilled. Drilling time logs and information furnished by a mud-logging unit are used to determine the top of the geopressured sand. A test run immediately after drilling through a sand of sufficient thickness is most effective because there is less probability of formation damage, invasion, and supercharging of the zone. In addition, the hole configuration would remain more stable and offer a better opportunity to obtain a good packer seat. The possibility of obtaining good packer seat and date would be enhanced by using multiple packers with pressure-distributing techniques. Two samplers could be run to recover flowing samples, with dual pressure and temperature recorders, multiple flow periods and closed-in-pressures. By utilizing all information from a good drill-stem test, valuable reservoir data could be obtained.

Conventional drill-stem tests have been successfully run below 22,000 feet. By using high-temperature packers and seals, a test covering an 8-hour flow time could be possible. However, the limited radius of investigation and the possibility of differentially sticking the drill string might be a factor making this method unattractive.

Deep- and Hot-Hole Sampling

A new method of reservoir sampling has been developed for high temperatures and pressure reservoirs containing H_2S and CO_2. The following description of this method is from a paper presented to the Symposium on Sour Gas and Crude of the Society of Petroleum Engineers of AIME, held in Tyler, Texas, November 11-12, 1974 (Montgomery and others, 1974).

> It was necessary to determine how we were going to bring a sample back to the surface under safe conditions that could be evaluated. This sample must be as near reservoir condition as possible. It should be uncontaminated and be in a condition that the sample could be qualitatively and quantitatively analyzed. To do this and meet practical and safe operating conditions, it was necessary to come up with a technique or method that would be reliable. It should be safe and be compatible with present-day drilling techniques and technology.

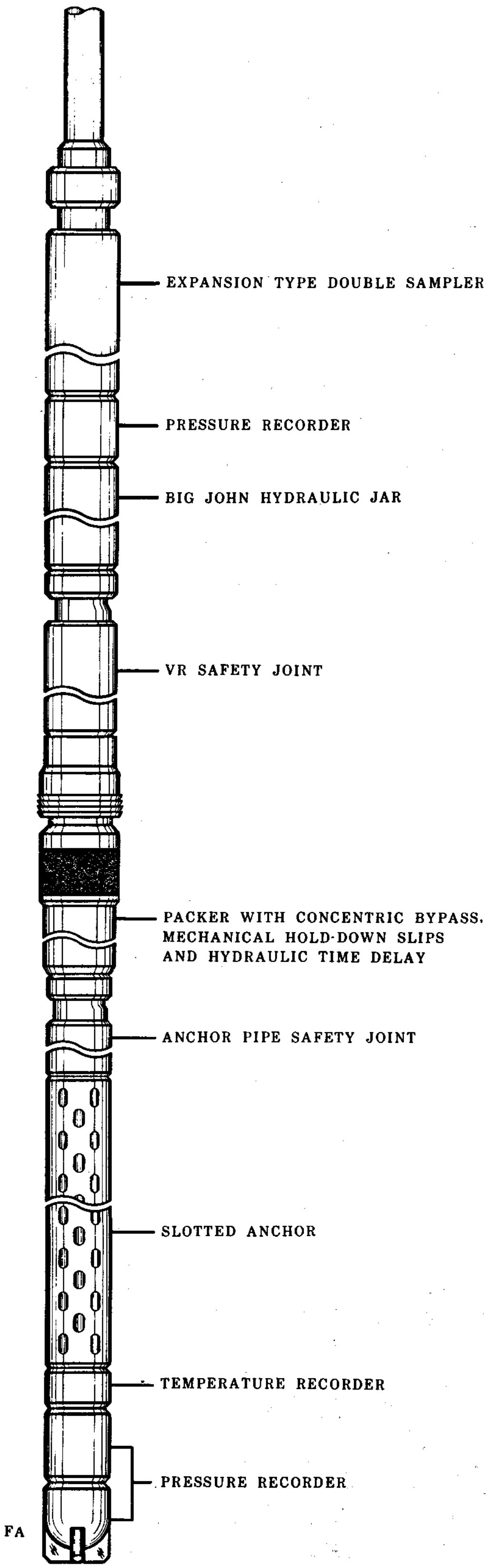

Figure 2. Deep-well SG testing string.

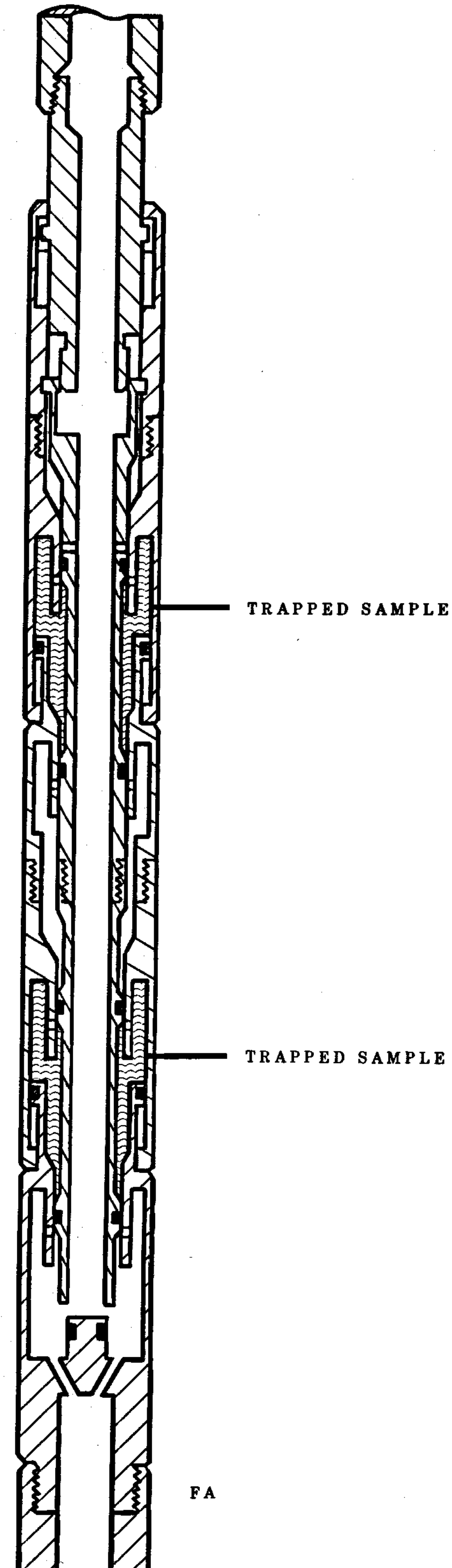

Figure 3. Expansion-type double sampler.

It was decided that we would use a method of sampling that would use several components and equipment of existing tools that were reliable and dependable. The testing string will be made up of two samplers that will be run in the drill string and be fully open to the fluids entering the drill pipe [fig. 3]. They would remain open until they are actuated at the proper time after the packer is set and the well is allowed to produce.

The drill pipe is run in the well with testing and sampling equipment attached. This configuration of tools does not have a valve in it and allows the drill pipe to fill up going in the hole. Now this might present a problem if there is H_2S entrained in the mud system. Then the drill pipe would be subjected to its damaging effects. There is a possibility that in circulating the hole in preparation for this type of work that we might spot on bottom fifty (50) or one hundred (100) barrels of treated fluid or whatever would be adequate. By placing this specially treated mud by displacement at the bottom of the hole, our equipment doing the sampling would be in this treated mud throughout the test. By placing one joint of inhibitor in the drill pipe as we go in the hole, it would coat the drill pipe as it was moved up the hole due to the "U" tube effect of the mud entering the drill pipe. A better solution would be to inhibit the whole mud system.

The method for obtaining a sample on reaching bottom is by using a metering system at the surface. Pump down the drill pipe a predetermined amount of light fluid, such as diesel fuel, displacing until the hydrostatic inside of the drll pipe would be less than the bottom-hole pressure [fig. 4]. We would then set the packer and release the pressure on the drill pipe at the surface allowing the well to produce back a predetermined quantity of fluid or gas and then close a valve at the surface [fig. 5]. The samplers are closed going in the hole and automatically cycle to the open position when the packer is set. The samplers may be closed when desired and will remain closed. We would then unseat the packer and allow the hydrostatic of the annulus back on the formation.

This presents several situations, one of them being that if you had not displaced enough fluid in the drill pipe to lighten its hydrostatic load, the well would not produce. The packer has withstood minimum differential pressure at this time so that you can unseat the packer and displace some more fluid down the drill pipe. Another factor is that there is no sudden opening of the tool or shock loading across the packer at high differentials. This allows the use of rubber goods for the packer element to be of a material that is already available to the industry. Therefore, the packer is not of a great concern. After an amount of fluid and/or gas is produced back into the drill pipe and it is assumed that the produced fluid or gas is of uncontaminated reservoir quality, the two samplers are then actuated and closed. This traps the fluid or gas for its return to the surface.

Two samplers will be run with these tools. The two samplers will have chambers that will telescope on retrieving them from the hole. This will allow the samplers to expand and reduce their pressure by this expansion and the reduction in temperature. It will be calculated so that these pressures will be below a safe pressure.

This is acceptable to most people with the exception of some of the reservoir engineers who wanted a sample as near reservoir conditions as possible. It was determined that in a laboratory it could be put back near original conditions.

I am sure that it is quite apparent to you that we would have a certain amount of this fluid or gas in the drill pipe and that there would be a necessity to remove it safely and not bring it to the surface uncontrolled. It was determined that we might use two methods; one of them would be to use a hydraulic open hole hold down packer, then pump the fluids back into the formation it was produced from, such as you would do on a squeeze job. This was determined as the most acceptable; however, if this is not possible, we would use the second alternative. With the control head still hooked up and after the equipment was moved off bottom, then we could reverse circulate.

It is quite apparent that all things that we will be attempting in this system are very practical as they have been done with few exceptions. Breaking down the formation could be difficult. It could create a vertical fracture that might grow as fluids were injected into the formation and bypass the packer. Breaking down the formation might create a loss circulation problem [fig. 6]. The other situation that is created is the reverse circulation in open hole. To change the flow patterns and the turbulence of fluids in open hole is not a readily accepted practice by some people. However, it was felt that if the packers and tools were off bottom a sufficient distance, it would allow free circulation and adequate area for any cuttings or sloughing to bypass the packers and equipment.

Pressure recording instruments and temperature recorders could be run. When the sample is removed from the hole and if it indicates that there is no sour crude or gas, a conventional open hole drill stem test could be run to get more extensive reservoir data.

CONCLUSIONS

1. The techniques discussed would serve as methods of recovering a flowing sample that would be representative of the produced fluids.

2. Testing equipment should incorporate a clock-actuated pressure and temperature recorder. The bottom-hole temperature and bottom-hole

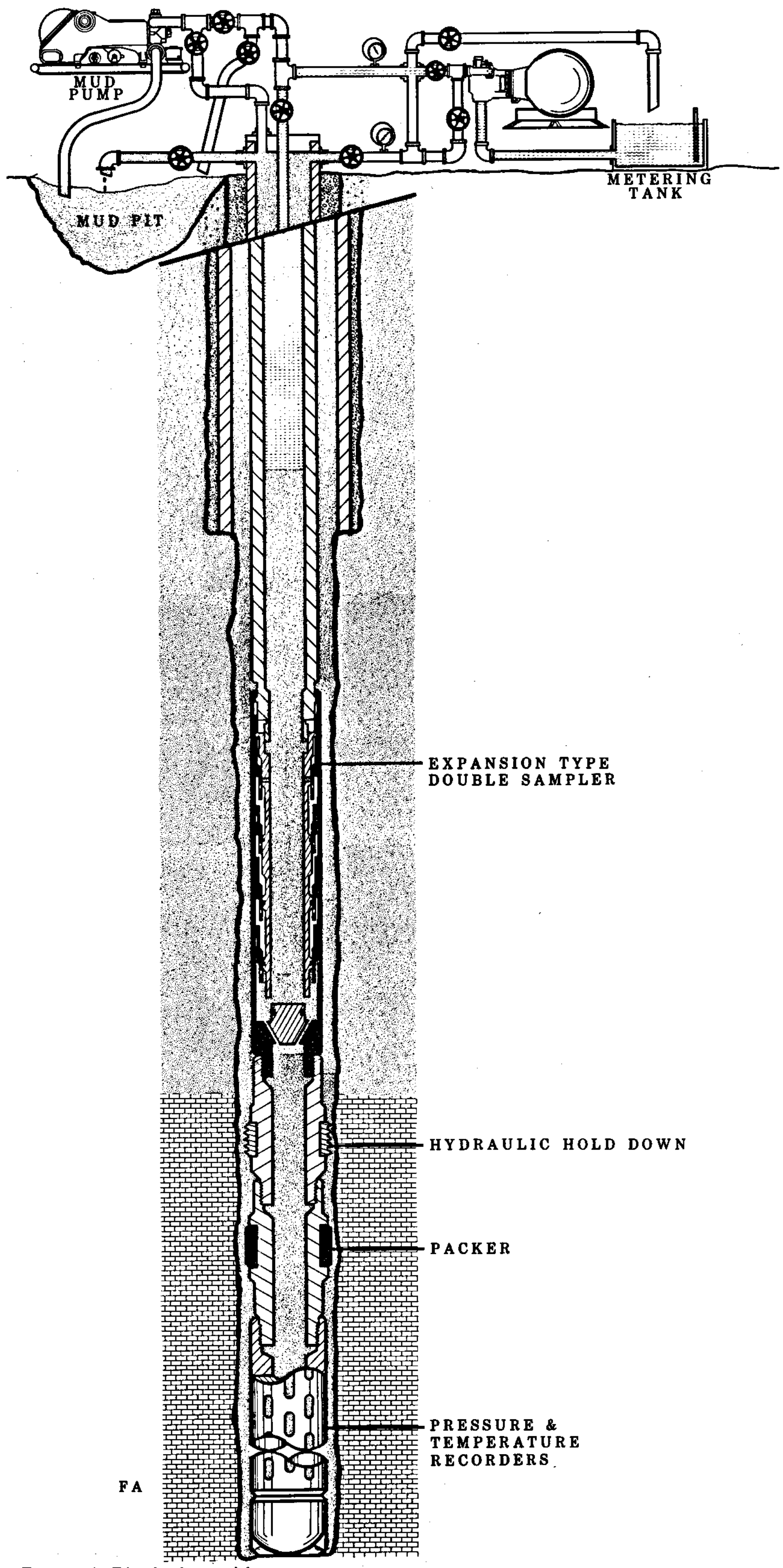

Figure 4. Displacing tubing.

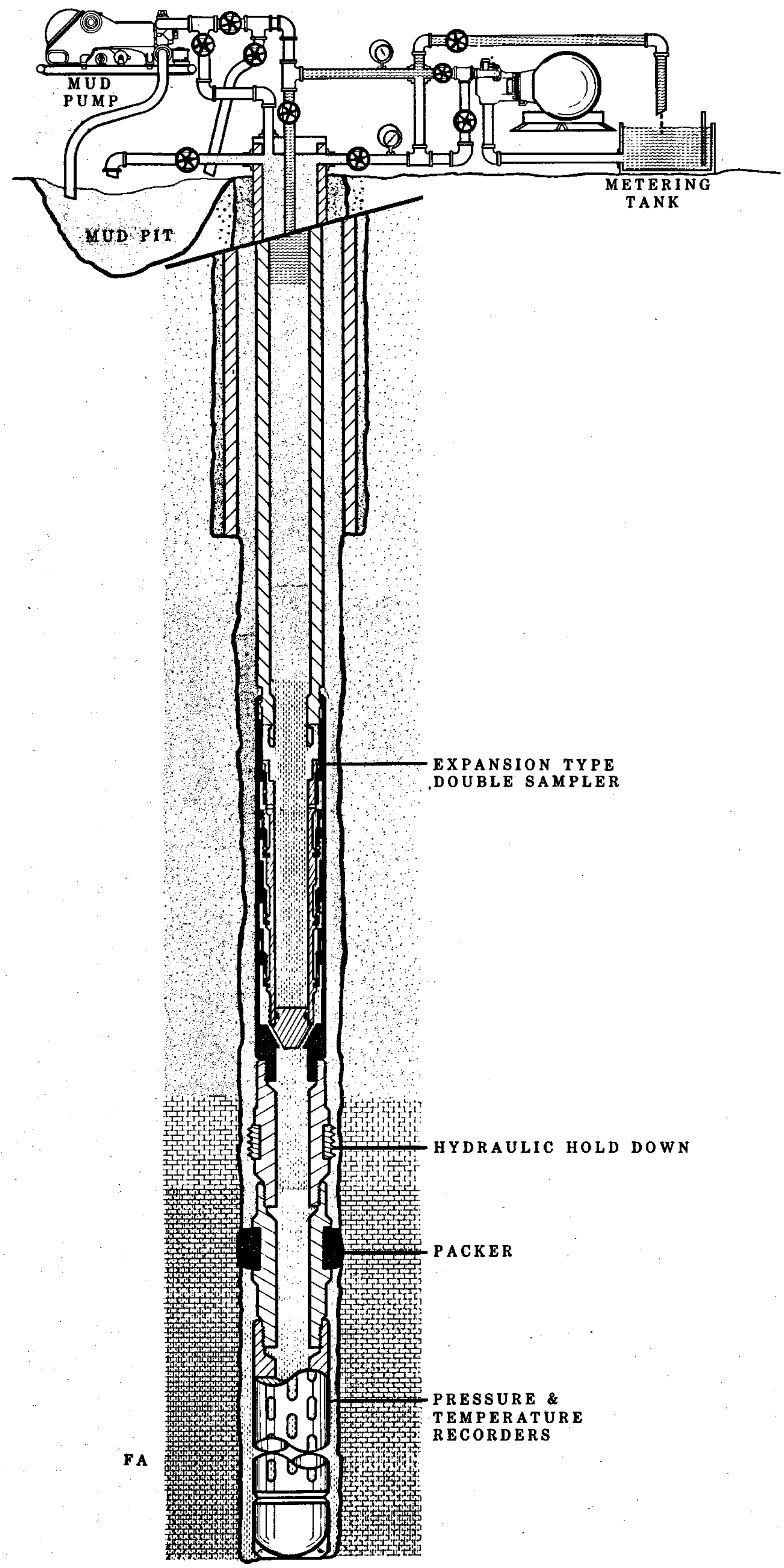

Figure 5. Producing the formation.

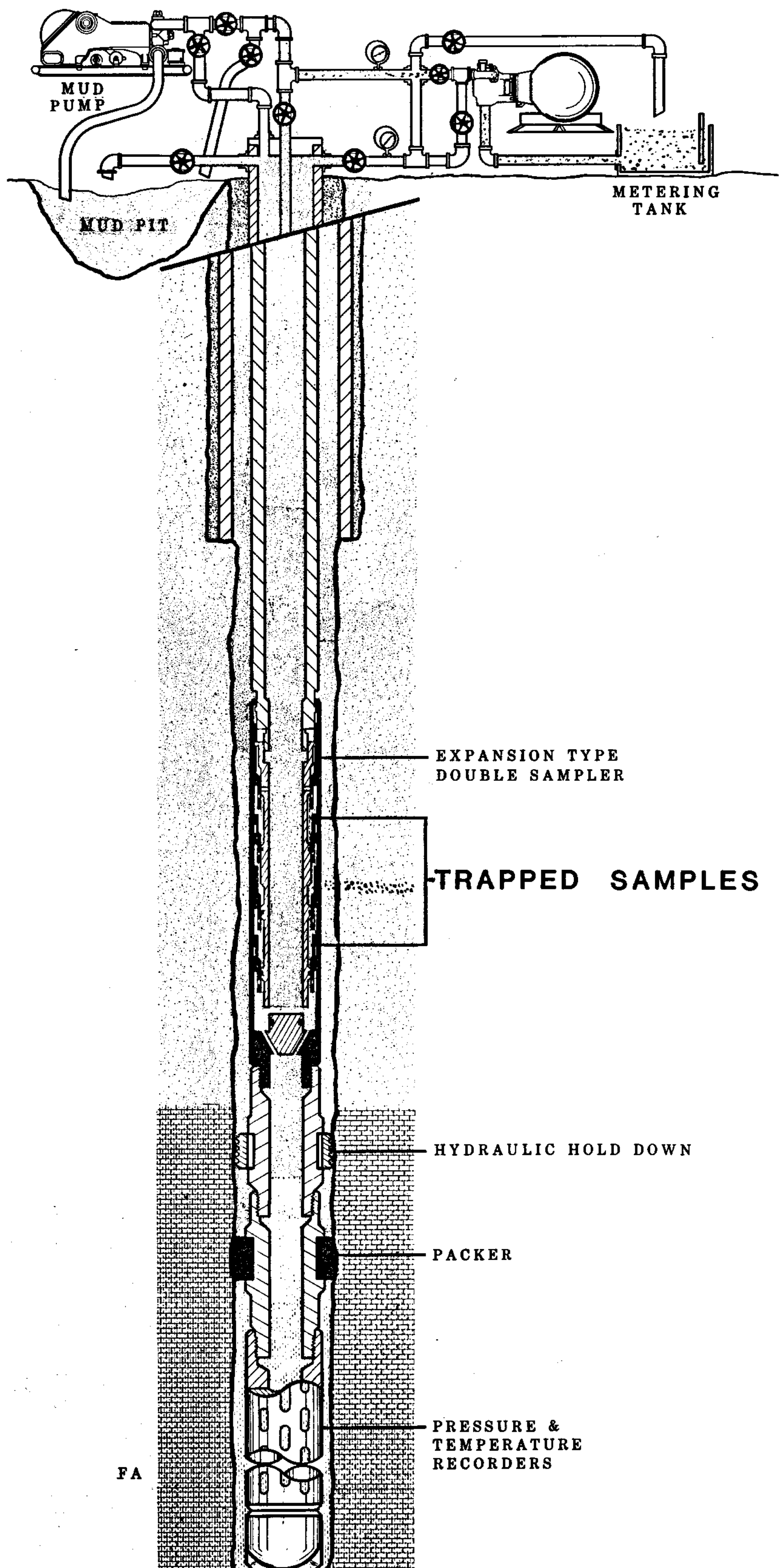

Figure 6. Displacing recovery in formation.

pressure would be adequately recorded to evaluate the aquifer.

3. Preferred testing procedures in geopressured zones would incorporate setting a 7-inch liner with a tie-back string to the surface and testing of the formation using a thermal-production packer and large tubing string. Using this method, production capabilities could be monitored over an extended period of time. An accurate evaluation of the producing zone could then be determined.

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Discussion

Osborne
Osborne-Hodges

Can you run with the stratapack?

Montgomery

Yes, sir. We can test anywhere in the Frio or Wilcox with that—yes, we've done it. Lots of people are a little reluctant to do it. You get differential sticking, but I don't feel we have any problems. You're limited on the time of flow that people will leave it on the bottom. You don't get a good drawdown. Your area of investigation may have permeability barriers. We have indications of dual and triple faulting as we test on back and it's very beautifully plotted out. I sure recommend testing. Of course, that's my bread and butter.